INDOOR AIR QUALITY ASSESSMENT

Watertown Fire Department Headquarters
99 Main Street
Watertown, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program

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Background/Introduction

At the request of the Watertown Fire Fighters Union, Local 1349, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health's (CEH) Bureau of Environmental Health Assessment (BEHA) conducted an indoor air quality assessment at the Watertown Fire Department Headquarters (WFD) at 99 Main Street in Watertown, Massachusetts. The request was prompted by occupant concerns/complaints of exposure to exhaust emissions.

On October 7, 2004, a visit to conduct an indoor air quality assessment was made to the WFD by Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program. During the assessment, Mr. Holmes was accompanied by Steve Ward, Director of the Watertown Health Department and Nancy Haynes, Health Agent.

The station is a two-story, red brick building constructed in 1991. The ground floor contains the engine bays, storage areas for fire fighting equipment and offices. The second floor contains bedrooms (for overnight staff), office space, kitchen and lounge. Windows are openable throughout the building. The front of the building has three garage doors that enclose each engine bay. A stairwell connects the engine bays to the second floor. Two fire poles with access to the engine bay are located in the second floor hallway near berthing areas.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor. Air tests for ultrafine particulates (UFPs) were taken with the TSI, P-Trak™ Ultrafine Particle Counter Model 8525.

Results

The station is staffed 24 hours a day, seven days a week and has an employee population of approximately 15-20. The station is visited by approximately 10-20 members of the public on a daily basis. The measurements were taken under normal operating conditions. Test results for general air quality parameters (e.g., carbon dioxide, temperature and relative humidity) appear in Table 1. Test results for UFPs and CO are listed in Table 2. A second set of test results for UFPs and CO measurements were taken after operating emergency response vehicles following a simulated call are also listed in Table 2.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) in all occupied areas surveyed, indicating adequate air exchange. However, the WFD does not have any means of mechanical ventilation, but uses windows to introduce fresh air. Air conditioning is provided during summer months by air handling units (AHUs) located in the attic (Picture 1). The AHUs do not have the capability to introduce outside air and can only recirculate air. AHUs are ducted to wall or ceiling mounted air diffusers (Picture 2). Ceiling-mounted return vents (Picture 2) draw air back to the AHUs via ductwork. These systems were not operating during the assessment. WFD officials reported that a preventive maintenance program was in place for air handling equipment.

A vehicle exhaust ventilation system is installed in the engine bays to remove carbon monoxide and other products of combustion; the system is described in detail under the Vehicle Exhaust portion of this report.

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings in occupied areas were measured in a range of 71^{o} F to 72^{o} F, which were within the BEHA recommended comfort range. The BEHA recommends that indoor air temperatures be maintained in a range of 70o F to 78o F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements ranged from 39 to 41 percent, which were within or very close to the lower end of the range of BEHA recommended comfort guidelines. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. During winter months outdoor relative humidity levels tend to drop. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northern part of the United States.

Microbial/Moisture Concerns

A number of areas had water-damaged ceiling tiles (Picture 3). Occupants reported that ceiling tiles became damaged as a result of condensation generated from operating the air conditioning equipment during the cooling season. Water-damaged ceiling tiles can provide a source of mold and should be replaced after a moisture source or leak is discovered and repaired.

Vehicle Exhaust

Under normal conditions, several sources of environmental pollutants can be present in a firehouse. These sources of pollutants, which primarily stem from fire vehicle operation, may include:

- Vehicle exhaust, which contains carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids, which contain volatile organic compounds (VOCs);
- Water vapor from drying hose equipment;
- Rubber odors from new vehicle tires; and
- Fire residues on vehicles, hoses and fire-turnout gear.

Of particular importance is vehicle exhaust. The use of fossil fuel-powered equipment (e.g. propane heaters, diesel or gasoline-powered vehicles, acetylene welding, etc.) involves the process of combustion. The process of combustion produces airborne liquids, solids and gases (NFPA, 1997). Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, carbon monoxide and particulate matter can produce health effects upon exposure. In order to assess whether contaminants generated by diesel engines were migrating into occupied areas of the station, measurements for carbon monoxide and airborne particulates were made and used to pinpoint the source of combustion products.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce acute (immediate) health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency (US EPA) has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000).

Carbon monoxide should not be present in a typical, indoor environment. If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were measured in a range of 0-2 ppm. Carbon monoxide levels measured in the WFD measured 0-3 ppm (Table 2). The measurement of 3 ppm was taken in the kitchen, which had several gas-fired cooking appliances.

Using carbon monoxide measurements alone to detect sources of combustion pollutants has limitations. If the source of combustion pollutants is allowed to dilute in a large volume of air within a building, carbon monoxide concentrations may decrease below the detection limits of equipment. As discussed, combustion of fossil fuels can also produce particulate matter of a small diameter [10 micrometers (μm)]. For this reason, a device that can measure particles of a diameter of 10 μm or less was also used to identify pollutant pathways from vehicles into the occupied areas.

The US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter (μg/m3) in a 24-hour average.

BEHA staff conducted air monitoring for airborne particulate with a TSI, P-Trak™ Ultrafine Particle Counter (UPC) Model 8525, which counts the number of particles that are suspended in a cubic centimeter (cm^3) of air. This type of air monitoring is useful for tracking and identifying the source of airborne pollutants by counting the actual number of airborne particles. The source of particles can be identified by moving the UPC through a building towards the highest measured concentration of airborne particles. While this equipment can ascertain whether unusual sources of ultrafine particles exist in a building or whether particles are penetrating through spaces in doors or walls, it cannot be used to quantify whether NAAQS PM10 standards have been exceeded. The primary purpose of these tests is identifying and reducing/preventing pollutant pathways.

Air monitoring for ultrafine particles (UFPs) was conducted around doors that provide access to the engine bay. Monitoring was also conducted in several areas on the first and second floor of the station. Measurements were taken prior to and after diesel engine operation. The highest reading for UFPs was taken in the engine bay, after diesel engine operation. These elevated measurements would be expected during the normal operation of motor vehicles in an indoor environment.

As mentioned previously, the station is equipped with a mechanical exhaust system to remove exhaust from the engine bays when vehicles are idled. The local exhaust system consists of two large manually-activated exhaust vents located at the rear of the engine bay (Picture 4). WFD personnel activate the system from a wall-mounted panel located at the front of the engine bay (Picture 5). WFD personnel reported that the system is typically activated when emergency vehicles are backing into the station, following an emergency response. This was observed by BEHA staff during the simulated call.

Although the engine bay is equipped with a mechanical ventilation system, a number of pathways for vehicle exhaust and other pollutants to move from the engine bays into occupied areas on both the first and second floors were identified (Figure 1). Spaces were observed beneath the doors off the engine bay, and light could be seen penetrating through these spaces (Picture 6). Clamshells (i.e., closures) around fire poles did not close completely, creating spaces (Picture 7). Elevated levels of UFPs were measured near these areas after operation of fire fighting vehicles (Table 2). These results demonstrate that the breaches are serving as pathways for diesel exhaust and particulates to move from the engine bay into occupied areas of the station.

In addition, the second floor windows located directly above local exhaust vents were open during operation of fire fighting vehicles (Picture 8). Under certain wind and weather conditions, exhaust emissions can penetrate or be drawn in/entrained through the open windows. Another possible pathway for exhaust emissions to migrate is through utility holes. The ceiling/walls of the engine bays are penetrated by holes for utilities. These holes can present potential pathways into occupied areas if they are not airtight. Each of these conditions presents a potential pathway for air to move from the engine bays to occupied areas of the station. In order to explain how engine bay pollutants may be impacting the second floor and adjacent areas, the following concepts concerning heated air and creation of air movement must be understood:

- Heated air will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.
- Heated air that is rising creates negative pressure, which draws cold air to the equipment creating heat (e.g., vehicle engines).
- Combusted fossil fuels contain heat, gases and particulates that rise. In addition, the warmer air becomes, the greater airflow increases.
- HVAC system operation (including rest room exhaust vents) can create negative air pressure, which can draw air and pollutants from the engine bays.

Each of these concepts has influence on the movement of odors to the second floor and areas adjacent to the engine bays. As motor vehicles operate indoors, the production of vehicle exhaust in combination with cold air moving from outdoors through open exterior doors into the warmer engine bays can place the garage under positive pressure. Positive pressure within a room will force air and pollutants through spaces around doors, utility pipes and other holes in walls, doors and ceilings. To reduce airflow into the second floor, these pollutant pathways should be sealed.

Conclusions/Recommendations

In view of the findings at the time of the assessment, the following recommendations are made:

1. Consider installing an automatic control to activate the engine bay exhaust system as engine bay doors open.
2. Continue to manually operate the engine bay vent system to create negative pressure in the engine bays. To help reduce exposure to airborne pollutants/particulates, activate the system upon departure and returning from emergency calls.
3. Ensure all doors are closed when accessing engine bays.
4. Ensure doors around engine bays are completely flush with threshold. Seal doors on all sides with foam tape, and/or weather-stripping. To create a duel barrier, consider installing weather-stripping/door sweeps on both sides of doors that provide access to the engine bay. Ensure tightness of doors by monitoring for light penetration and drafts around doorframes.
5. Ensure second floor windows are closed during engine operation to prevent entrainment of vehicle exhaust.
6. Consider installing an exhaust vent stack for the engine bay exhaust system that extends over the height of the roof, as depicted in Picture 9. Please note that the Massachusetts Building Code states that vents removing pollutants must be either ten feet from or two feet above the fresh air intake of the ventilation system (SBBRS, 1997; BOCA, 1993).
7. Ensure all utility holes are properly sealed in both the engine bay and terminus sides to eliminate pollutant paths of migration.
8. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to

minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

9. Replace/repair water-damaged ceiling tiles. Examine the area above and behind these areas for microbial growth. Disinfect areas of water leaks with an appropriate antimicrobial.

10. Consider contacting the WFD's HVAC vendor to determine if the AC system can be retro-fitted so that fresh outside air be mechanically provided throughout the year.

11. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

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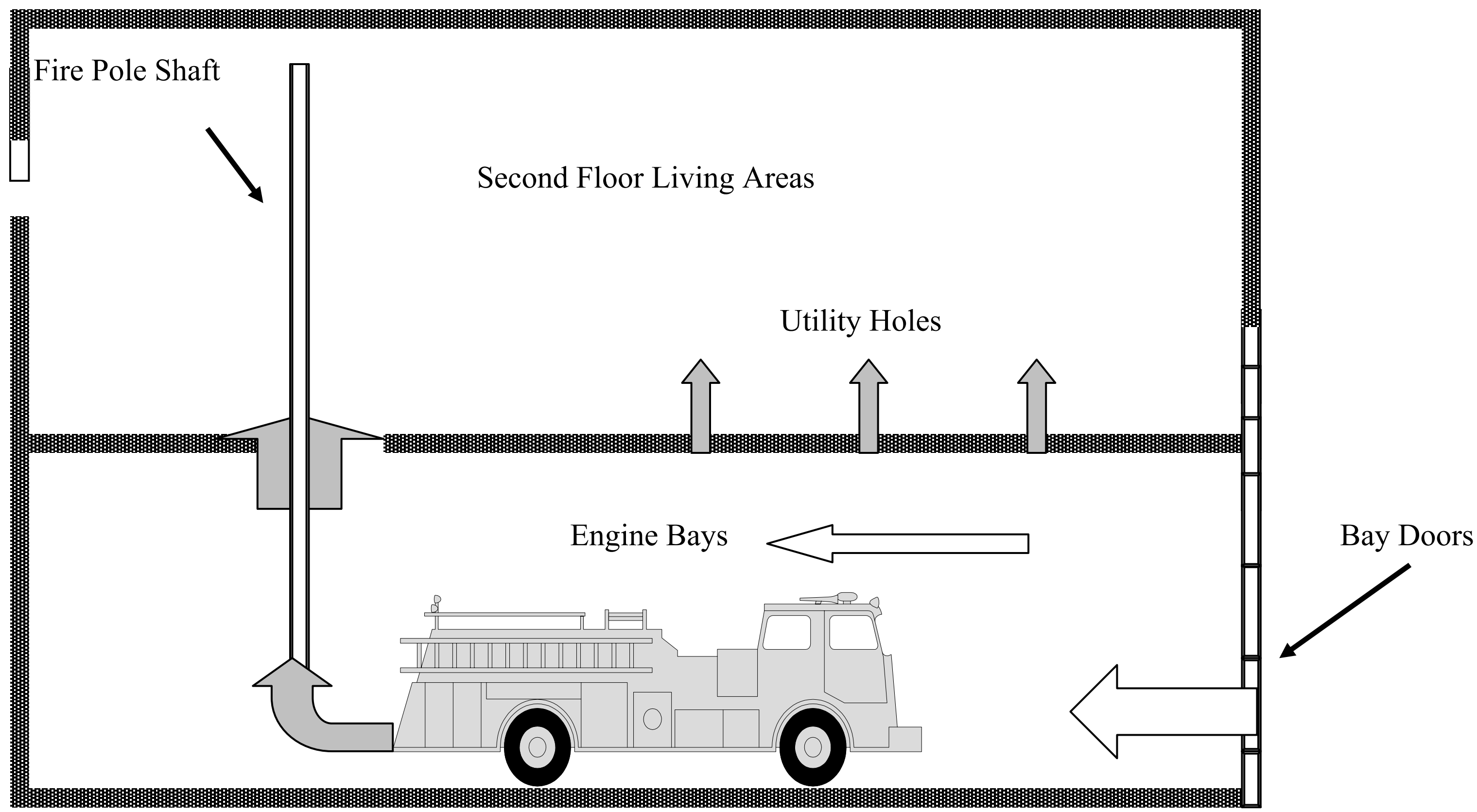
NFPA. 1997. Fire Protection Handbook. 18th ed. Cote, A.E., ed. National Fire Protection Association, Quincy, MA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R. 1910.1000 Table Z-1-A.

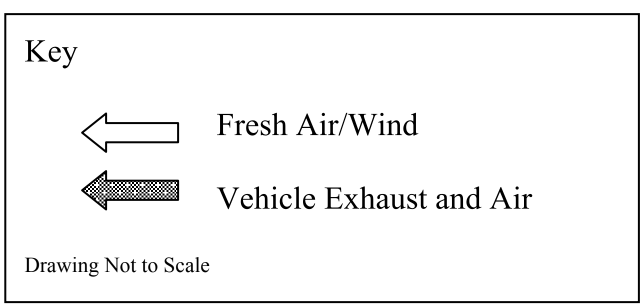
SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

US EPA. 2000. National Ambient Air Standards (NAAQS). US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC. http://www.epa.gov/air/criteria.html.

Figure 1 **Potential Pathways of Air and Pollutant Movement from Engine Bays into Occupied Areas***



* Note exhaust is minimized via the vehicle exhaust ventilation system



Picture 1

AHU in Attic

Picture 2

supply vent return vent

Supply and Return Vent for AC System

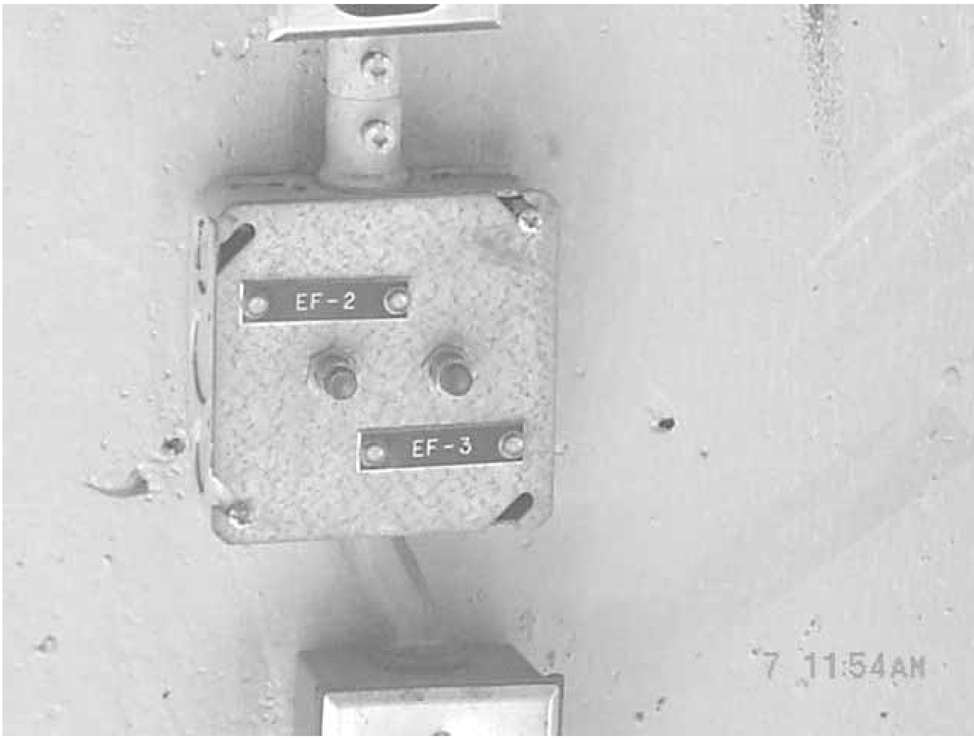
Picture 3

Water Damaged Ceiling Tiles in Kitchen Area

Picture 4

Manually Activated Local Exhaust Fans at Rear of Engine Bay

Picture 5

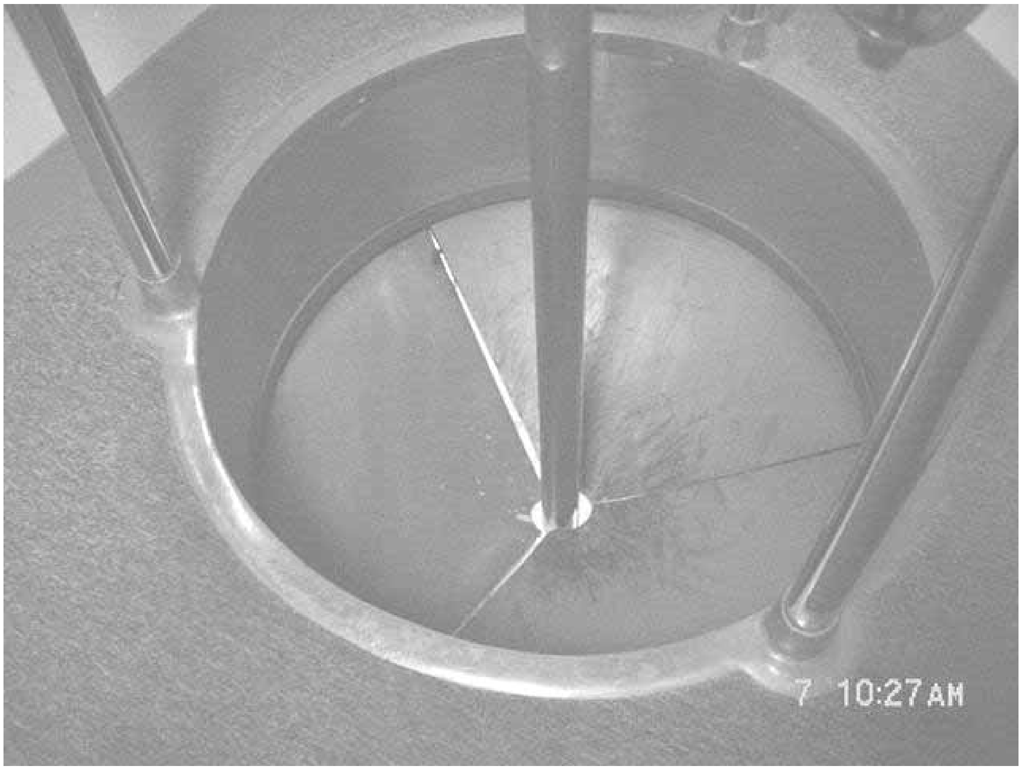


Activation Panel for Local Exhaust System Located at Front of Engine Bay

Picture 6

Example of Space beneath Engine Bay Door

Picture 7



Spaces around Fire pole Clamshell Closures

Picture 8

Open Second Floor Berthing Area Windows Directly over Local Exhaust Vents

Picture 9

Exhaust Vent Stack

Vehicle Exhaust Vent (40 West Central Street Firehouse, Franklin, MA), Note the Position and Height of Vent away from Windows at rear of Building

TABLE 1

Indoor Air Test Results – Fire Dept. Head Quarters 99 Main St., Watertown, MA – October 7, 2004

Location	Carbon Dioxide (*ppm)	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Background	375	73	39					Clear sunshine, NE winds light and variable
Engine Bay	404	69	38	2	N	N	Y	2 large exhaust fans on rear wall of bay (manually activated)
Staff Service Office	611	71	41	0	Y	N	N	Spaces under door (across from engine bay)
Union Office	630	71	41	1	Y	N	N	
Fire Prevention Office	622	72	41	1	Y	N	N	
Chief's Office	503	72	40	1	Y	N	N	
Upper Hallway, Fire Pole 1	512	72	40	0	N	N	N	Spaces around fire pole
204	494	71	40	0	Y	N	N	
Upper Hallway, Fire Pole 2 (kitchen)	423	71	39	0	N	N	N	Spaces around fire pole

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

Indoor Air Test Results – Fire Dept. Head Quarters 99 Main St., Watertown, MA – October 7, 2004

Location	Carbon Dioxide (*ppm)	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
207	452	71	39	0	Y	N	N	Window open above engine bay exhaust system

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results* for Ultrafine Particulates and Carbon Monoxide
Fire Dept. Head Quarters 99 Main St., Watertown, MA – October 7, 2004

Location	Carbon Monoxide (**ppm) Before	Carbon Monoxide (**ppm) After	Ultrafine Particulates 1000p/cc^3 Before	Ultrafine Particulates 1000p/cc^3 After	Comments
Background	0-2	0-2	18-26	22-29	Moderate to heavy traffic/constructio n
Engine Bay	0	0	31.3	100	
Staff Service Office	0	0	19.3	17.6	
Union Office	0	0	20	16.7	
Fire Prevention Office	0	0	18.7	17.8	
Chief's Office	0	0	16.8	13.4	
Upper Hallway, Fire Pole 1	0	0	19.3	31.5	
204	0	0	17.9	12.9	
Upper Hallway, Fire Pole 2 (kitchen)	0	0	19.6	39.1	
207	0	0	17.6	11.6	
Kitchen	1-2	3	27.8	31.8	Gas-fired appliances in operation

**** ppm = parts per million parts of air**
*** testing before and after starting diesel engines and response vehicles for simulated call**